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**Environmental Hydraulic Impacts of River
Diversions into An Impoundment**

by

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Abstract

The Drainage and Irrigation Department, Malaysia (DID) is planning on flow diversions of Gombak and Batu Rivers into an ex-mining Batu pond as one of flood mitigation measures in the urbanizing Klang River basin. The pond will also be used for recreational activities during non-flooding period. An impact study on the pond has been carried out using a 2-D hydrodynamics and water quality model which concentrates on the transport of total suspended solids (TSS). Active flow activities and pollutant transport take place mostly in the southern region of the pond resulting the water to be unfit for the designated use.

Introduction

Uncontrolled rapid urbanization in a river basin has introduced floodings and water pollution problems which damaged the property and quality of life. Water pollution can adversely affect the environment causing deterioration of aquatic ecosystems. The deterioration of water quality in waterbodies due to rapid urban and industrial development in a catchment resulting the water resources to be unfit for their beneficial uses.

The Klang River basin is the most important, urbanized, populated and probably the most polluted river basin in Malaysia (Low, 1990). The urbanization also causes the recurrent of floodings in the Klang River and its tributaries. A mitigation program has been initiated to protect the downstream flood-prone areas including the city of Kuala Lumpur by providing adequate detention capacity. The Drainage and Irrigation Department (DID) is embarking on flow diversions of Gombak and Batu Rivers into a 530-hectare ex-mining Batu pond as one of the mitigation measures (JICA, 1989). Low water velocity is one of the hydraulic features of ponds. Therefore, they often become sinks for pollutant (Thomann, 1987). The inflows of both rivers which carry significant amount of total suspended solids (TSS) would have considerable impacts on long term water quality in the pond.

A detailed study on water quantity control had been carried out by the DID. However, a study on hydrodynamics and impact on water quality was not taken into consideration. Therefore, a water quality modelling study using a 2-D model for the pond has been carried out.

Study Area

The study area which is located in the upper part of the Klang River Basin which is not classified as flood-prone (JICA, 1989). There are about 13 ex-mining ponds in the ponds in the upper Klang River basic with surface area ranging from 0.7 to 90 hectares. The Batu detention pond is a 53-hectare ex-tin mining pond bordering the western bank of the Batu River, between 6.0 km and 8.4 km points upstream of the Batu and Gombak Rivers confluence (Fig. 1). The maximum depth of the pond is 25 m while average depth is 13.3 m. The tin mining activities in the area were in operation from 1949 to 1983 using dredgers and gravel pumps resulted in the irregular (non-uniform) pond bed profiles.

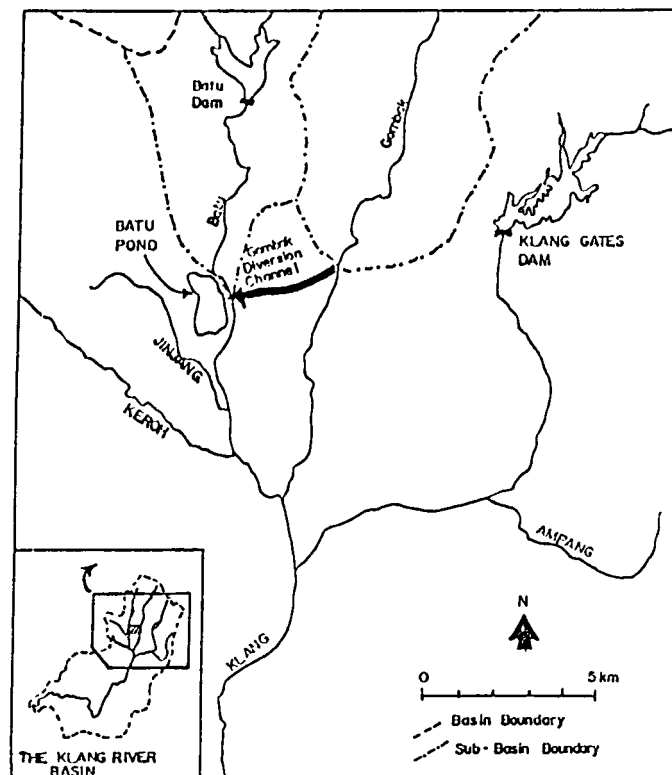


Fig. 1 : Study Area

Diversion of Rivers and Batu Detention Pond

The Batu detention pond and Gombak diversion channel are among the urgent flood mitigation projects in the Klang River basin. The 3.25 km long open channel will be constructed to direct a designed $60 \text{ m}^3/\text{s}$ of 100 year return period stormwater from Gombak River into the Batu detention pond. A 55 m wide and 2.6 m high overflow weir will be constructed at the entrance. Batu River which is flowing nearby the pond will also be diverted into the pond. A $60 \text{ m}^3/\text{s}$ of 100 year return period stormwater is designed to enter the pond. Fig. 2 illustrates the layout of the proposed Batu detention pond.

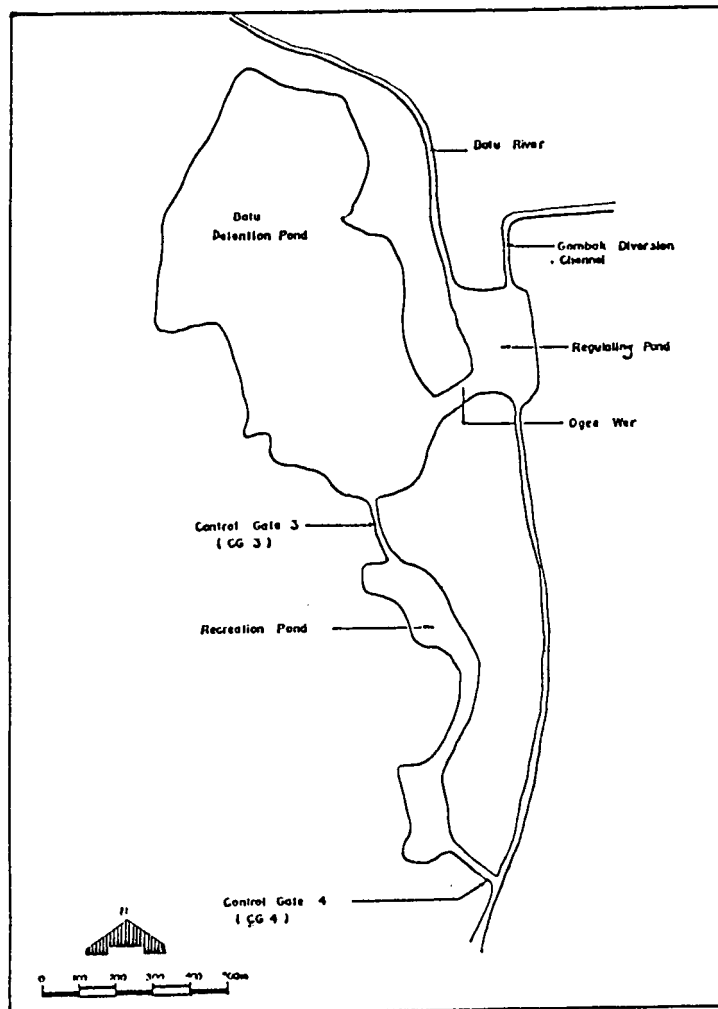


Fig. 2 : Layout of the Proposed Batu detention pond

The characteristics of the proposed regulating and detention ponds are shown in Table 1. The detention pond will serve as flood control and also for recreational activities during non-flooding period.

Table 1: Details of regulating and detention ponds

	Regulating Pond	Detention Pond
Surface Area (sq.m)	55600	533155
Max. Depth (m)	4.5	25.0
Lowest Water Level (m)	El. 42.0	El. 38.2
Highest Water Level (m)	-	El. 43.7
Max. Water Level (m)	-	El. 45.5
Detention Time (hours)	0.5	36.0

(Source : DID, Malaysia)

Field Study

Analysis on the pond water samples shows that the present quality is good with high dissolved oxygen (DO), low turbidity and total suspended solids (TSS). However, samples from both rivers indicate low DO level, high turbidity and TSS levels (observed TSS = 210 mg/l). The sampling is carried out during low flows. Based on the field study, TSS will give significant impact on the pond water quality after diversion takes place.

Low vertical water temperature gradients (1 to 2°C) at various stations indicate weak thermal stratification or almost non-existence in the pond. Maximum surface water velocity of only 3 cm/s is measured during windy condition: no water velocity is detected in calm period.

Water Quality Model

The 2-D hydrodynamics and water quality model used in the study is known as RESPOND, developed in the USA. The model consists of hydrodynamics and water quality programs. The hydrodynamics program solves momentum and continuity equations (Eqn. 1 to Eqn.3).

$$\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} + g \frac{\partial \zeta}{\partial x} + \frac{\tau_{bx}}{\rho H} = 0 \quad (1)$$

$$\frac{\partial V}{\partial t} + U \frac{\partial V}{\partial x} + V \frac{\partial V}{\partial y} + g \frac{\partial \zeta}{\partial y} + \frac{\tau_{by}}{\rho H} = 0 \quad (2)$$

$$\frac{\partial \zeta}{\partial t} + \frac{\partial(HU)}{\partial x} + \frac{\partial(HV)}{\partial y} = 0 \quad (3)$$

where U and V are depth averaged velocity components; H is total water depth ($h + \zeta$); h is still water depth; ζ is free surface displacement; τ_{bx} and τ_{by} are bottom shear stresses. Meanwhile, the water quality program computes the concentration distribution of a constituent by solving the advective-dispersive transport equation (Eqn.4).

$$\frac{\partial \zeta}{\partial t} + \frac{\partial (HUC)}{\partial x} + \frac{\partial (HVC)}{\partial y} - \frac{\partial (HD_x \frac{\partial C}{\partial x})}{\partial x} - \frac{\partial (HD_y \frac{\partial C}{\partial y})}{\partial y} \pm HS_A = 0 \quad (4)$$

where C is constituent concentration; D_x and D_y are longitudinal and transverse dispersion coefficients and S_A is source/sink term.

Numerically, the model adopts the Alternating Direction Implicit central finite difference (ADI) technique. The additive fluxes in transport equation are solved using Skewed Upwind Difference Scheme (SUDS) [Wu, 1992].

Results and Discussions

Several modifications are made such as a rectangular pond shape and outlet location due to the limitations of the model. Simulations are performed on the IBM RISC 6000 workstation for total time of 48 hours. Computer time is large due to small time step and mesh sizes requirements in the model. The results simulation cover:

. Velocity distributions

The flow diversion will take place for 14 hours. The resulting temporal variations of velocity distributions in the detention pond are presented in Fig. 3. The initial velocity vectors are only significant near the inlet and gradually decrease along the flow path towards the outlet. As time increases, the flow is distributed all over the pond with the increase in magnitudes. Maximum velocity of 4 cm/s is predicted at time of 12 hours after the diversion takes place. Once the inflow ends, the velocity vectors start to diminish. Formations of horizontal circulation are also predicted. Active flow activities only occurs in the southern region of the pond due to the momentum from pond inlet to the outlet.

. TSS transport and distributions

A TSS pollutograph of constant 210 mg/l is assumed to enter the pond during stormwater diversion. Dispersion coefficients, $D_x = 20 \text{ m}^2/\text{s}$ and $D_y = 5 \text{ m}^2/\text{s}$ are adopted in the study. The temporal distributions of TSS in the pond are illustrated in Fig.4. Initially, turbulence mixing takes place near the inlet where inflow acts as a driving force. As time increases, the movement of TSS isoconcentration lines is predicted towards the pond outlet. Little or no mixing is anticipated to occur in the northern region of the pond. The TSS concentration in the pond rises from 3.55 mg/l initially to a maximum of 76 mg/l after 48 hours which only affected the southern region of the pond.

Conclusions and Recommendations

With the assumed concentration of 210 mg/l to enter the pond during diversion, the TSS in the Batu detention pond will increase to a maximum of 76 mg/l in the southern region after 48 hours. The degradation of water quality will cause this region to be unfit for recreational activities which allows a maximum TSS concentration of 50 mg/l (Class IIB, National Water Quality Standards). Further flow diversion will certainly deteriorate the pond water quality. The proposed inlet and outlet should be located further away from one to another to avoid flow short-circuiting. Installation of baffles in the pond is also recommended. This will optimize the pond surface area for pollutant distribution.

The computer model has become an important tool in the study. However, a monitoring study must be carried out for the purposes of calibration and verification of the model.

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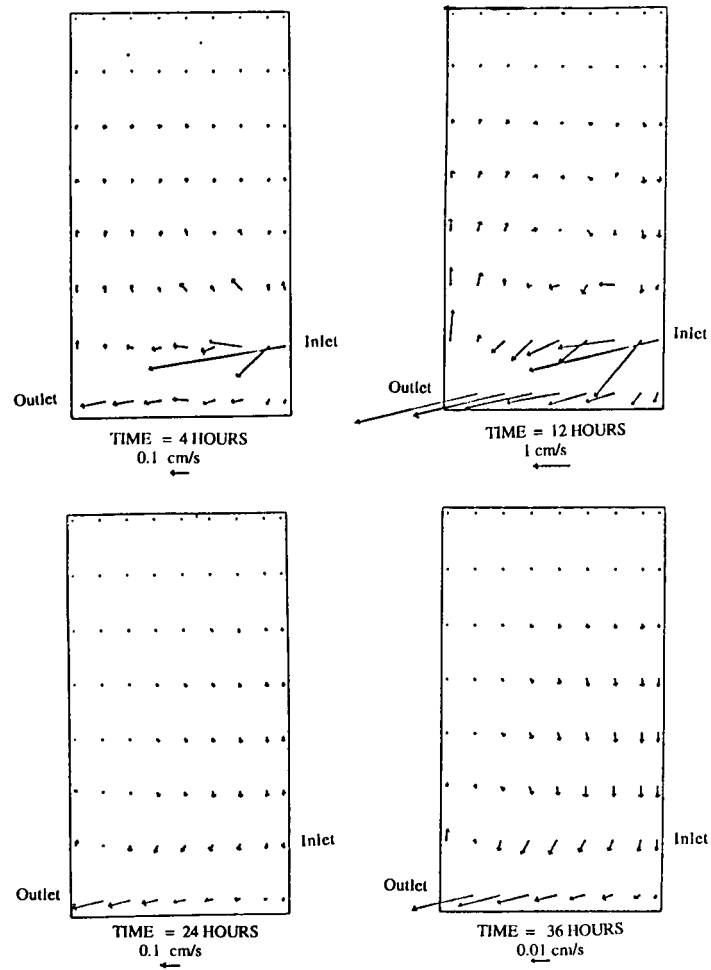


Fig. 3 : Velocity Distributions in the Pond

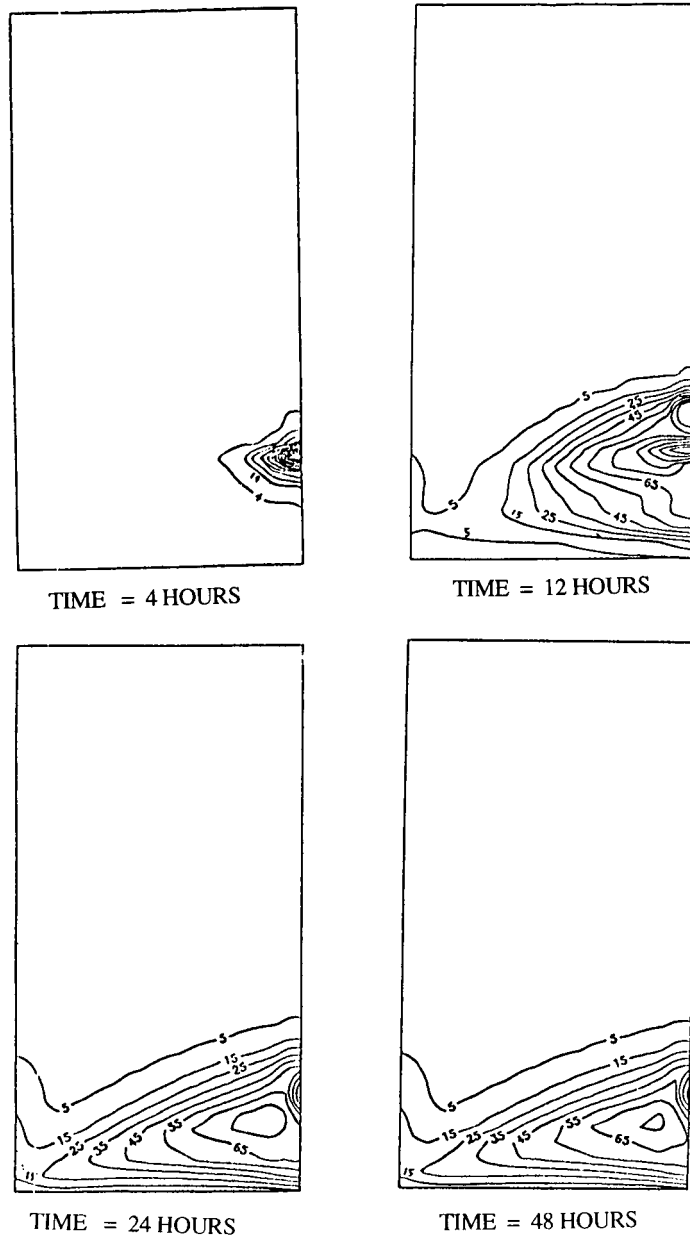


Fig. 4 : Distributions of TSS Concentration in the Pond